Smart Manufacturing in the Electronics Industry – An Overview

Jay Gorajia, Global Services Director, PCB Design and Electronics Manufacturing

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The pace of change is incredible

Age of disruption

- Digital disruption is shaving 45% off incumbent companies’ revenue growth and 35% off their EBIT.
- More than 50% of the Fortune 500 has disappeared since 2000.
New Business Models

From bookstore to e-book

From Yellow Pages to marketplace

From record store to streaming

From taxi to ride-sharing
Change is Inevitable
Digital Darwinism is a significant threat

“More than 50% of companies that attempt to move to a digital model will fail.”

Source: John Chambers, McKinsey & Company Report
March 2016
Technological forces transforming industry

Changing the way products come to life
- Generative design
- Intelligent models
- System of systems

Changing the way products are realized
- Intelligent automation
- Additive manufacturing
- Advanced robotics

Changing the way products evolve
- Cloud ecosystems
- Knowledge automation
- Big data analytics
What does it mean to you?
Industry 4.0 definition

1st revolution: Mechanization, steam and water power
2nd revolution: Mass production and electricity
3rd revolution: Electronic and IT systems, automation
4th revolution: Cyber physical systems
Why?

- Germany was looking for a way to get back into manufacturing with the threat of China/Asia cost structures driving innovation and business out of Germany

- Looking for infrastructure, technology and marketing to drive improvements such that they can compete
  - Government sponsored initiative, with academia (Fraunhauer Institute), industry leaders (SAP, Siemens, Bosch, Daimler, BMW, etc), and technology partners

- Drive enough change so that democratization of technology and capabilities push down to Tier 2 and Tier 3 manufacturers (SBEs), scaling manufacturing capacity and capabilities
  - Further reduce the reliance on pushing NPI, and some volume production overseas
Expected Outcomes

- Flexible order processing
- Efficient resource management
- Connected, reliable production
- 100% traceability and quality assurance
- Self-optimizing manufacturing and production
- Consistent engineering
- **Digital Continuity** throughout the lifecycle of a product

The “Digital Thread” needs to include an **eco-system of partners** working together, to achieve true benefits to cost, quality, while managing schedule risk.
Smart Manufacturing Key Tenants

**Connectivity** – The ability of all players (machines, humans, smart factories, partners, etc.) to be connected

**Real-time** – The ability to collect and analyze data and make decisions in real time (by humans or AI)

**Modularity** – Flexible adaptation of Smart Factories to changing market requirements (Lot-Size-One)

**Decentralization** – The ability of systems to make decisions on their own (Product Aware Manufacturing)

**Human-machine interaction** – The ability of machines and humans to interface in a standardized way

**Virtual entities** – The ability to build a virtual representation of the real world (Digital Twin)

**Source:** SMART FACE-Project Consortium (2014).
Smart Manufacturing Considerations

SERVICES PLATFORM

Engineering

Foundation Conformance

Quality Management

Shop-Floor Execution

Business Intelligence

ENGINEERING

Process Preparation
- CAD/BOM merge
- SMT programs
- AOI / ICT support
- Operator Standard
- DFT / DFA
- Stencil design

Production Plan
- Work order scheduling
- Automated material grouping
- What-if scenarios
- Actual-vs-planned analysis

FACTORY MGMT.

MSS Workspace
- Central platform
- Management control
- Shop-floor modelling
- Product flow design
- Users/Skills management

Quality Mgmt.
- Process data collection
- Final assembly
- Visual inspection
- Repair station
- Paperless documentation
- RMA work

Shop-Floor Mgmt.
- Performance monitoring
- Material verification with MSD/AVL
- Material traceability
- LED binning
- Off-line setup
- Splicing

Material Mgmt.
- Just in time material logistics
- Kanban logistics
- Warehouse management

SHOP-FLOOR DATA ACQUISITION CLIENTS

Quality Mgmt.

Quality Management

Business Intelligence

WEB APPS

Dashboards & reports
- Real-time dashboards
- Configurable KPIs
- Material and process traceability
- OEE analysis
- Yield/DPMO reports
- Custom reports

ERP INTEGRATION – INFORMATION HIGHWAY (inc. REST API)

ERP

PLM

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ERP

PLM

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Long History Of Data Collection

In 1980’s data collection was done mostly manually
- Logging number of products produced at end of every hour or shift
- Manual logging of down time of machines
- Manual logging of issues
- Consumed operator time
- Added accuracy risk
Long history of data collection

Machine Vendors and factories started deploying sensors, counters and some progress.

Then came the age of machine interfaces
- RS-232 / RS485 (serial port)
- Parallel ports
- Ethernet (was originally developed for debugging purposes only, but added functionality due to demand to customers)

The age of electrical risk!
- PCs connections to SMT/PTH machines, caused electrical discharge, surge, etc.. risks
Legacy Standards

Several standards were attempted 10-20 years ago
• IBM’s MAP and TOP, CAN (now used in automotive),

GEM-SECS
• Became standard in semiconductor industry
• Standardises infrastructure and control, but not actual data content (needs peer to peer agreement)

CAM-X
• Most modern approach, although network heavy
• Complex machines were not supported completely
• Standard was compromised through the need for proprietary customization
Standards Challenges

Different formats, connections and protocols
Different amounts of data represented in different context
Varying accuracy and complexity
• Machine down time may be due to material load error or parts out, … not necessarily reflected in output
Standards Challenges

… And it’s still true today

… And what do you do with the older machines?
Industrial Internet of Things (IIoT)

- Scalable, reliable, plug & play data acquisition and control
- Built-in interfaces to majority of automated & manual stations
- Machine & process control
- Deliver complete, accurate data
- High data integrity & security:
  - 3-day data retention
  - Built-in power reserve
  - Automated data recovery
- Plug & Play deployment:
  - Scalable distributed architecture
  - Built-in PoE
  - Built-in network switch
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Physical line connections

- Valor IoT Manufacturing Line Controller
- Flexible Machine OML Producer
- Advanced Machine OML Producer
- Output Converter Interface
- Hand-held scanner
- Fixed scanner
- PCB Sensor
- Temperature Humidity Vibration
“Smart Factory” Infrastructure

Use the data
SDK

Distribute the data
OML, Factory Gateway

Qualify the data
Root-cause and bottleneck identification

Add perspective
Complete line and factory view

Interpret & normalize
OML

Add perspective
Build-in machine interfaces

http://omlcommunity.com/
IloT – Normalized Intelligent Data

- Real time performance dashboards
- Factory/Line/Machine/module
- Fully configurable
- Performance KPIs
- Product flow visibility
- Test results & statistics
- Process status
ANALYTICS

Smart Data – Smart Decisions

DATA COLLECTION

- Component-level (material, quality, process metrics)
- Pink-level (material, quality)
- Lot-level (material)
- PCB-level (material)

Year


Data Records per work order

10,000,000,000
100,000,000
100,000
100

10,000,000,000
100,000,000
100,000
100

PCB-level (material)
Lot-level (material)
Leveraging Advanced Analytics to Transform Business

**Descriptive**
What happened?

**Diagnostic**
Why did it happen?

**Predictive**
What happens next and when?

**Prescriptive**
When this happens, take these steps.

- Fast Contextual Search
- Performance Analytics
- Advanced Data Visualization

- Fast Contextual Search
- Performance Analytics
- Advanced Data Visualization
- Discovery

- Performance Analytics
- Advanced Data Visualization
- Predictive Learning
Machine Learning Algorithms

**Unsupervised**
- Clustering & Dimensionality Reduction
  - SVD
  - PCA
  - K-means
- Association Analysis
  - Apriori
  - FP-Growth
- Hidden Markov Model

**Supervised**
- Regression
  - Linear
  - Polynomial
- Decision Trees
- Random Forests
- Classification
  - KNN
  - Trees
  - Logistic Regression
  - Naive-Bayes
  - SVM
Academia
- normally at the forefront.
Paper using Neural Network and SOM to Analyze Solderability Quality
- Luikkonen, 2010

Figure 16: Classification of diagnostic methods according to Venkatasubramanien et al. (2003).

The data from a lead-free wave soldering process include 1073 rows with 40 variables in columns. The variables are presented in Table 1.
Predictive Analytics Algorithm modeling for Yield
- 2000

Decision Support System to Predict the Manufacturing
Yield of Printed Circuit Board Assembly Lines

Felipe Helo

A Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
Complex Adaptive Systems, Publication 6
Cihan H. Dagli, Editor in Chief
Conference Organized by Missouri University of Science and Technology
2016 - Los Angeles, CA

Application of Neural Network in Shop Floor Quality Control in a Make to Order Business

Rajkamal Kesharwani\textsuperscript{a}, Cihan Dagli\textsuperscript{a}, Zeyi Sun\textsuperscript{a*}

\textsuperscript{a}Missouri University of Science and Technology, Rolla MO 65409, USA
There are many many more.....
Making It Real
Intelligent NFF Filtering

“Based on the measurement results, the AI-engine will propose the ideal inspection conditions from the Koh Young Template. Ultimately, Auto Programming maximizes efficiency by minimizing job creation time.”

“Using Machine Learning algorithms, it’s possible to ‘learn’ NFFs and eliminate them from the defect list”
Analytical Classification

Using Machine Learning to ‘learn’ what a defect may be, and identify them, on the fly!
- Push notifications
Example: Dynamic Control Limits

Dynamically update your Control Limits…based on actual process characterization..not arbitrary ‘wish’
Computational Process Control (CPC)

Applied Materials is developing an evolution in supervised process control that uses Industry 4.0 advanced data analytics techniques combined with modeling data, metrology data, virtual metrology data, process data and domain knowledge into a next generation process control model.
Automatically trigger equipment maintenance based on real-time quality metrics

Machine-to-machine closed-loop feedback
Modeling of Predicted Yield is out there…and available

<table>
<thead>
<tr>
<th>Config Name</th>
<th>Auto Placement (Discrete)</th>
<th>Auto Placement (Non-Discrete)</th>
<th>Press Fit</th>
<th>Press Fit Quality</th>
<th>Received Defective Parts</th>
<th>Screen Print/Reflow (Non-Discrete)</th>
<th>Screen Print/Reflow</th>
<th>Thru Hole Placement</th>
<th>Thru Hole Soldering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stellarica</td>
<td>35</td>
<td></td>
<td>284</td>
<td>1000</td>
<td>5000</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>1000</td>
</tr>
<tr>
<td>Rigidtronics</td>
<td>36</td>
<td></td>
<td>284</td>
<td>500</td>
<td>5000</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>1000</td>
</tr>
</tbody>
</table>

![Formula: DPMO = \( \frac{D}{O} \times 10^6 \)](image)

\[
D = D_s + D_E
\]

Structural and electrical defects are calculated with the number of components and joints on the board, the structural and electrical \( DPMO_c \) (components) and \( DPMO_j \) (joints) and with the structural and electrical multiplier:

\[
D_s = \frac{(C_B \times S_C \times M_S)}{10^6} + \frac{(J_B \times S_J \times M_S)}{10^6}
\]

\[
Y_n = e^{-D_F}
\]

Where:

- \( C_B \) = Components on Board.
- \( J_B \) = Joints on Board.
- \( S_C \) = Structural DPMOc.
- \( S_J \) = Structural DPMOj.
- \( M_S \) = Structural Multiplier.
- \( E_C \) = Electrical DPMOc.
- \( E_J \) = Electrical Multiplier.
ASM (SiPlace) Process Expert Solution

- Automatic feedback for stencil alignment
- Automatic feedback of key parameters
- DEK and ASM SPI Smart Connectivity
Real World example – Siemens Electronics Factory, Amburg Germany

- Implementation of Industry 4.0

- Co-Sponsorship between Fraunhour institute, Siemens and Government of Germany to create a ‘model factory’.

https://www.youtube.com/watch?v=Q4BK4qy0Ts4
## Connecting “Services” to the Supply Chain

### Value driver: End-to-end real-time supply chain visibility platform
- **Speed to market**
  - Lack of end-to-end (E2E) visibility across supply chain performance, to enable decision making
  - Installed end-to-end real-time supply chain management software for centralized inventory management & supplier and site performance monitoring
  - $80M savings in supply chain costs
  - **Origin industry**: Pharma
  - **Applicable industry**: Consumer, Automotive, Aerospace, Chemicals

### Value driver: Single platform for real-time supply chain decisions
- **Resource productivity and efficiency**
  - Lack of E2E visibility across supply chain performance to enable decision making
  - Automated purchasing, sourcing, inventory modeling and tracking onto a single connected platform, enabling simulations and fact based decision making
  - 20% improvement in productivity
  - 5% reduction in SC coordination costs
  - 5% improvement in on-time delivery
  - **Origin industry**: Aerospace
  - **Applicable industry**: Consumer, Automotive, Pharma, Chemicals

### Value driver: Aggregate demand across end-to-end supplier network
- **Resource productivity and efficiency**
  - Delays in supply chain due to poor communication of demand needs across network of sites and suppliers
  - Deployed a material demand aggregation engine to maps all parts used across all the suppliers that deliver to all sites in the manufacturing network. The engine groups the common parts used at different points in the process, monitors part purchase points and creates visibility to all supplier tiers
  - 3-25% reduction in raw materials purchasing costs
  - Trim long tail supplier lists
  - **Origin industry**: Aerospace
  - **Applicable industry**: Automotive, Engineering, Chemicals

*Source: McKinsey*
Building Services Around Data
SUMMARY

- Vendors are developing solutions to common challenges affecting cost, quality and speed – TODAY

- Industrial Internet of Things hardware are connecting equipment, humans and processes, to drive normalized, intelligent data – TODAY

- Advanced Analytics – using Machine Learning Algorithms are providing Predictive and Prescriptive intelligence – TODAY
Change is Inevitable

- Full-fledged Smart Manufacturing may be a few years out
  - But:
    - There are already proven improvements cited in Germany and around the world, as more companies adopt smarter manufacturing processes and technology
    - Your customers are shifting, expecting more digital collaboration and expecting a ‘digital partner’

How can you leverage this transformation for more efficiencies, cost controls, tighter customer partnerships, and ultimately, more business?
Any Questions?
Thank You!

Jay Gorajia

Jay_Gorajia@mentor.com
Jay.Gorajia@Siemens.com
Director, Global Consulting Services
PCB Design and Manufacturing Consulting
Mentor Graphics Corporation

http://blogs.mentor.com/jay-gorajia